

A DIVISION OF THE SINGER COMPANY

# HIGHLIGHT SUMMARY

Advanced Simulation Technology

# A S T



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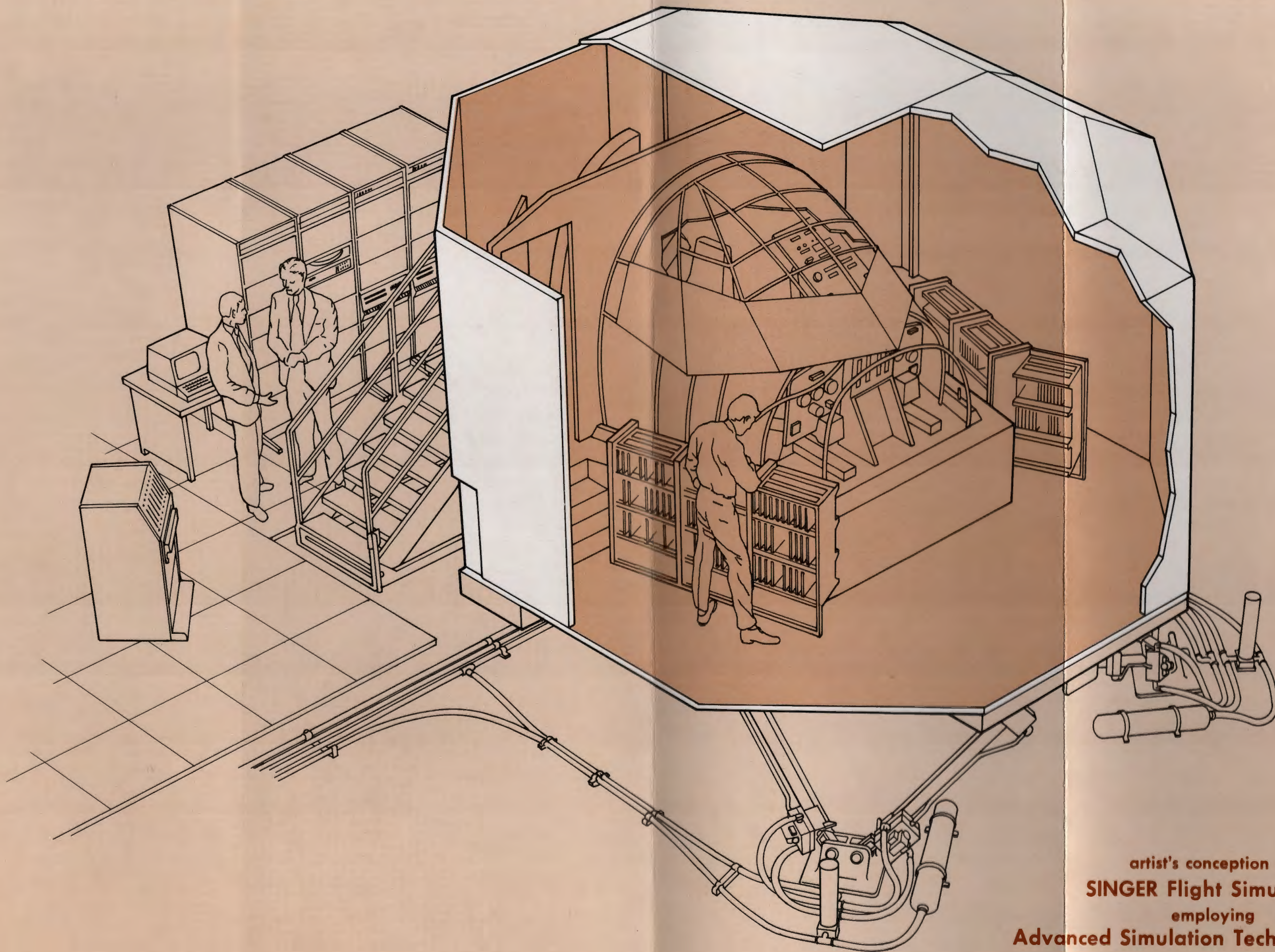
HIGHLIGHT SUMMARY  
ADVANCED SIMULATION TECHNOLOGY (AST)

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## FOREWORD

This document provides a brief overview of Link Division's Advanced Simulation Technology (AST) program, which was initiated early in 1973 for the purpose of effecting significant improvements in the performance, reliability, maintainability, and life-cycle cost of LINK\* flight simulators. The AST program has now culminated in a revolutionary new approach to simulator design that abandons traditional esthetic concepts in favor of the many practical benefits that modern electronics packaging techniques can provide. Every major aspect of simulator design has been touched by the program, as explained on the following pages, and Link is extremely pleased with the end result — an AST simulator design (see artist's conception, following page) that promises to set new industry standards for performance, operational availability, and cost-effectiveness.



artist's conception of  
**SINGER Flight Simulator**  
employing  
**Advanced Simulation Technology (AST)**

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## HIGHLIGHTS OF ADVANCED SIMULATION TECHNOLOGY (AST) PROGRAM

In the early 1960's, flight simulator designers turned to digital rather than analog computation techniques to solve the sophisticated technical problems associated with the simulation of complex, high performance aircraft. This technological change made it economical to extend and refine the simulation models while concurrently offering levels of accuracy and resolution that had previously been unattainable.

The decade of the 1970's has brought a new set of unique challenges to the industry. In view of the international energy crisis and persistent inflation, simulation equipment must not only be technically superior to meet present and projected requirements, but must also be designed in such a way that simulator costs do not follow projected inflationary trends.

In 1973, Link initiated a far-reaching, long-term development program entitled Advanced Simulation Technology (AST). This program had three objectives:

- 1) To utilize new technology as the means by which improved equipment performance could be realized without attendant increases in cost and as a means of partially offsetting the impact of inflation on acquisition costs.
- 2) To adopt an equipment standardization philosophy which would benefit both manufacturer and user.
- 3) To consider the customer's cost of ownership as a major design criterion and develop systems and techniques that reduce such costs.

It became apparent early in the program that these objectives could only be met a complete restructuring of the design of simulation hardware. It also was apparent that the electronic, electromechanical, and hydraulic equipment industries had sufficient new technology available that would allow such a restructuring to be accomplished.

Development programs commenced in early 1974 in five major equipment areas:

- 1) Simulator interconnection system
- 2) Electrical power distribution system
- 3) Aural cue synthesis
- 4) Flight control loading simulation
- 5) Cockpit motion simulation

The following paragraphs discuss the basic concepts associated with these programs, the means by which system techniques have been improved, and the principal advantages offered by each new system development. Because of the long-term development effort already completed on the AST program, Link is able to offer a simulation product that features the latest technology, yet avoids risk associated with procuring prototype systems. Beyond the prototype units built under the Link-funded development program, these systems are being utilized on a number of military programs, thus offering additional assurance of equipment integrity and standards.

The basic AST technological concepts are designed for the 1980's to reduce the potential of equipment obsolescence. Extensive built-in test is one of many additional equipment benefits that Link is able to offer to commercial airlines without a corresponding escalation of equipment cost. Link is determined to provide its customers with the best possible equipment, at acquisition costs that are anti-inflationary, and with features that substantially aid the customer, in the cost-of-ownership area, over the lifetime of the equipment.

#### Simulator Interconnection System

The interconnection system encompasses all electronics and wiring required between the digital computer and the simulator's flight compartment panels, controls, indicators, and instrument assemblies. The interconnection system of the typical

present-day simulator is a maze of interconnecting cables, interface cabinets, and wired backplanes which connect conversion and signal conditioning electronics that are physically diversified and normally remote from the cockpit input sources and final drive loads. The basic system concept results in a mass of related technical documentation, prevents the implementation of any cost-effective equipment diagnostic system, and, because it involves so many assemblies, is difficult to troubleshoot. Further, the inordinate number of system connections compounds the problem of equipment reliability, and the number of different types of components has become an acute problem because of the high rate of technical evolution within the component industry.

Therefore, a radical departure from existing system concepts was required to provide the much-needed improvement in this important equipment area. Figure 1 illustrates the AST interconnection system and compares it with conventional techniques.

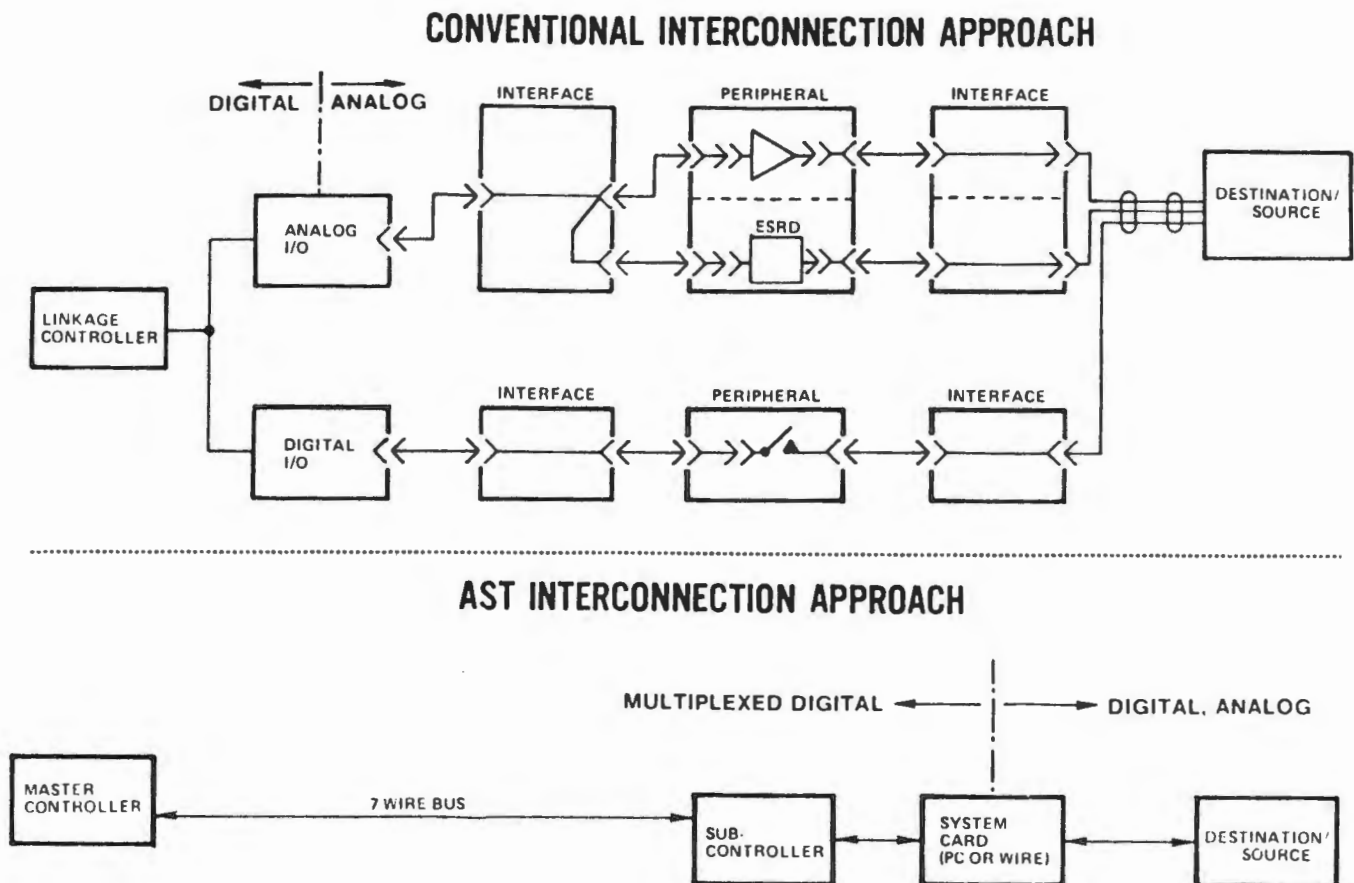


FIGURE 1 AST VERSUS CONVENTIONAL INTERCONNECTION SYSTEM

The AST system employs a digital bus concept, with all communications and transmissions performed digitally. It allows all of the system functions associated with driving or receiving information from the cockpit systems to be constrained to single assemblies (system cards). This means that the extensive wiring and cabling traditionally employed between major equipment and interface cabinets can be eliminated.

Figure 2 indicates the physical characteristics and distributive features of the system. A single master controller interfaces with the digital computer and communicates with up to 19 subcontrollers on a common transmission bus. Each subcontroller in turn passes along signal data to one of 16 system cards which it controls. The advantages of this approach to simulator interconnection are manifold:

- o Computer Interface via Direct Memory Access (DMA) - The system interfaces with the computer in the same fashion as any high-speed computer peripheral device. This means that CPU and bus transfer times are minimized.

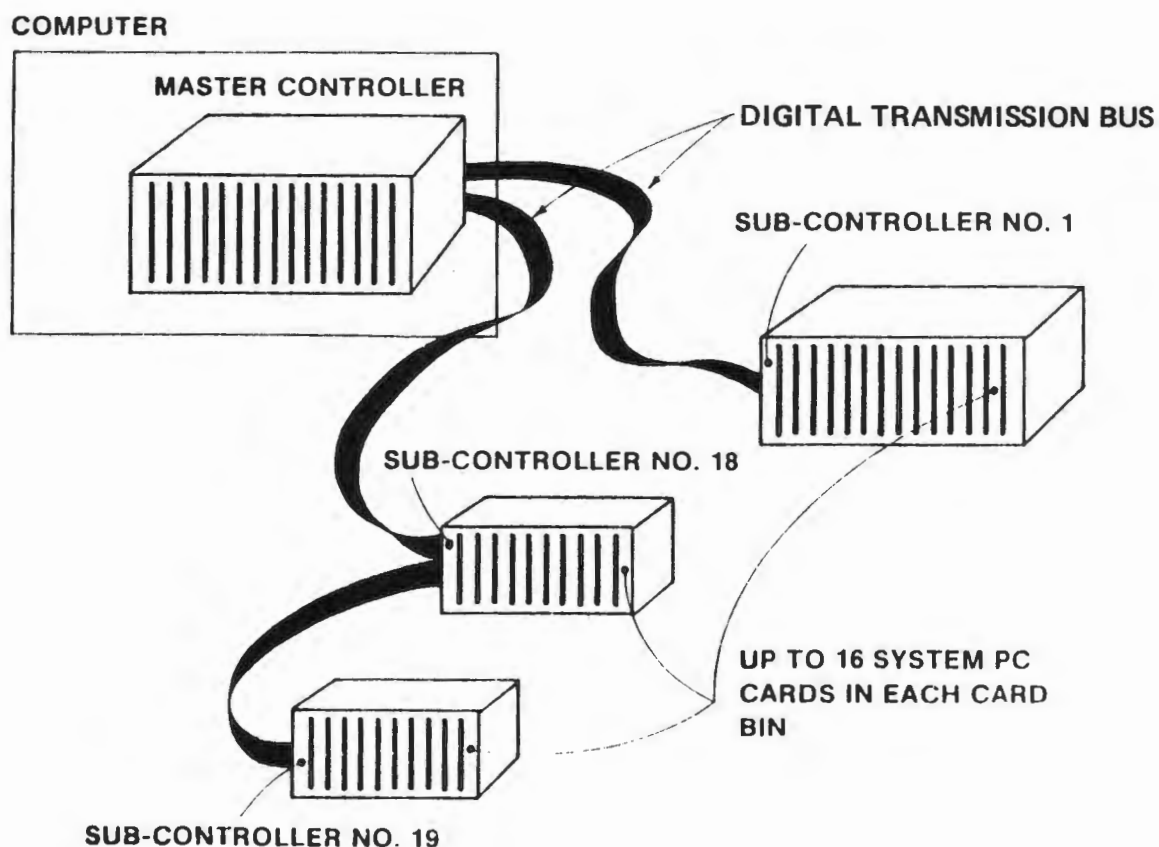


FIGURE 2 AST INTERCONNECTION SYSTEM CONFIGURATION

- o Data Pool Organization - Because of a unique map directory system built into the master controllers, a high degree of flexibility is inherent in the system. This feature is especially convenient when periodic updates to the simulator are required to reflect changes in aircraft configuration.
- o Formatting - The system performs all data formatting with no computer intervention required.
- o Random Address Capability - The system operates in a full duplex mode, either synchronously or asynchronously as desired. While most normal message service update is of a repetitive nature, the system possesses random address capability. That is, the order in which the data is processed can be changed without changing memory locations in the computer common data pool. Further, within the constraints of buffer memory, selected system cards can be updated at various iteration rates. This feature is useful in avoiding latency (time delays) between critical systems (e.g., motion, control loading and visual).
- o Single Cable Transmission - A single cable provides the entire interconnection between the computer location and all system electronics. Maximum transmission distance is 300 feet (91 meters).
- o Reliability of Communications - In addition to dual differential transmission design, the entire system utilizes real-time communication testing. All messages to the system cards are acknowledged by the receiver before data is transmitted, and all data received by the system cards is fully buffered and checked before updating conversion devices. This feature reduces the possibility of transients affecting a training program in progress.
- o Component Commonality - A high degree of component commonality exists in the system. Further, the repetitive character of the electronics is straightforward and easy for maintenance personnel to understand. A single type of card file is utilized and both signal and power buses are standardized.

- o Dedicated Conversion Electronics - Of major significance is the fact that dedicated digital-to-analog (D/A) converters are used throughout the system. Conversion from digital to analog form takes place near the load (instrument, servo, etc.), resulting in high signal-to-noise ratios. The elimination of multiplexed sample-and-hold techniques also removes time delays associated with such systems. Discrete input signal design is such that a range of voltages from microcircuit levels to beyond +28 volts can be interfaced through the same device.
- o Automatic Test Features - The digital bus concept, in addition to providing the means by which better technical performance and reliability is achieved, has allowed the incorporation of automatic test features which provide a significant reduction in equipment maintenance time and cost. Figure 3 illustrates the extensive self-diagnostic capability that is built into the system. Closed-loop testing provides fault isolation capability throughout the system. Of special significance is the fact that many of these tests are performed automatically, without any computer intervention, while the simulator is being utilized concurrently in a training mission. The real-time monitor test, for example, tests every single input and output conversion device at least once every 5 seconds while training is in progress. The result of detecting an error is an automatic printout similar to that shown in Figure 4. The system identifies faults to a single system card, and for subsequent off-line repair, by virtue of the word and bit address structure, will isolate the failure on the card to within three chips in most instances. Analog test conversion hardware is tested for calibration prior to conducting such tests, thus providing an accuracy in the readout that is suitable for making any calibration adjustments.
- o Additional Test Features - The master controller is equipped with a local maintenance panel to provide full "look and enter" capability. An addition, a remote decimal readout capability is available which allows connection to the system bus, thus providing remote computer memory readout. For "off-line" repair of the system cards, a single card file and subcontroller card enables troubleshooting in the maintenance area, utilizing data received on the transmission bus, thus providing an extremely flexible and inexpensive tool when contrasted with test consoles of the past.

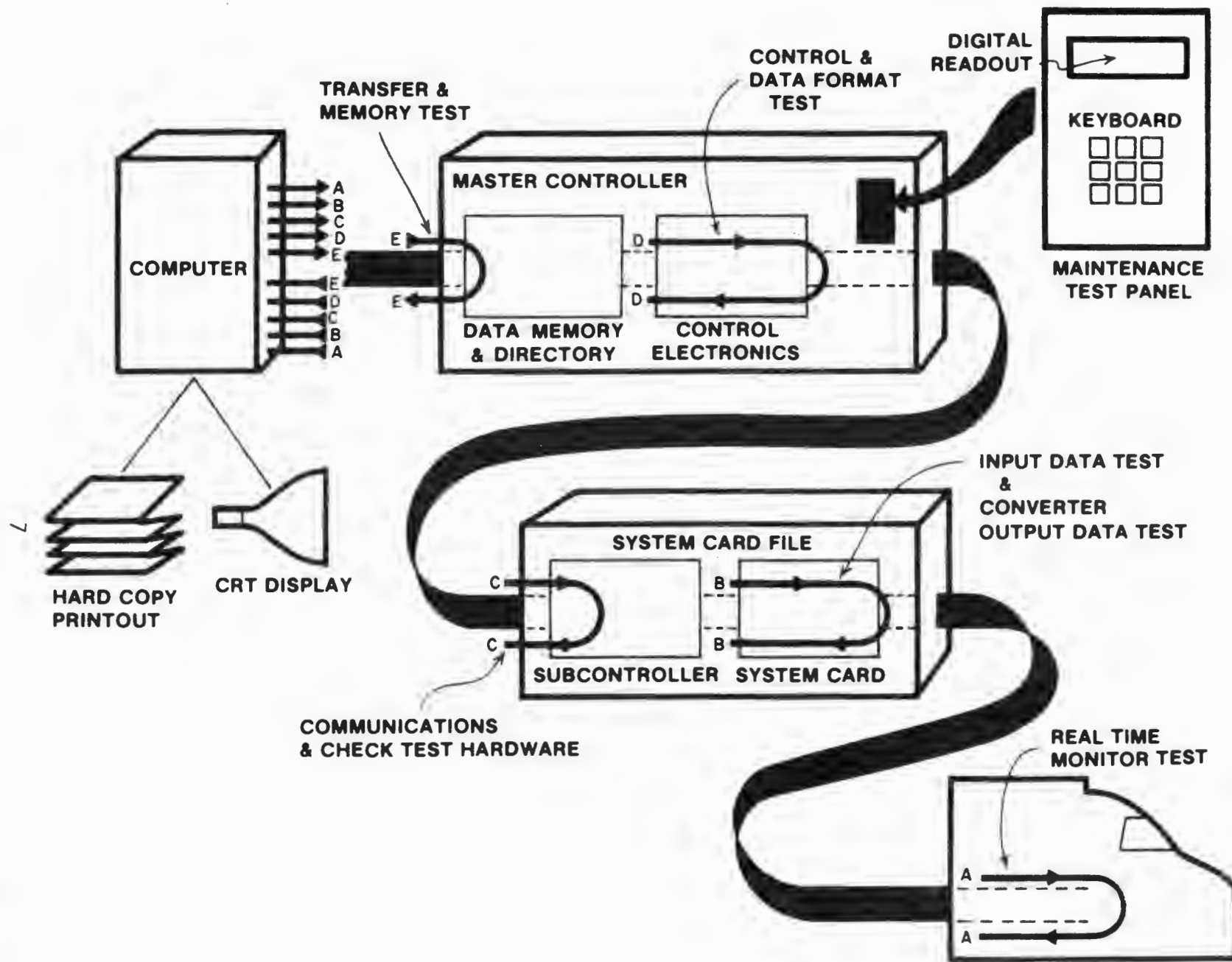


FIGURE 3 AUTOMATIC TEST SYSTEM

# TEST ERROR WORD EVALUATION

ICS-LOADER AND TEST ROUTINE VERSION 1.0 6/19/75  
OPTIONS IN EFFECT:  
TEST WORD ERROR EVALUATION

## ERROR DIAGNOSTICS

OUTPUT PORTS INHIBITED: 5 6 7

TEST MODE AT FAILURE WAS 5 (TEST OUTPUTS)

### TEST MODE ERRORS

ERROR NO. 1 SYSTEM CARD ADDRESS = 173 WORD ADDRESS = 2 *Address of Failure*  
ANALOG WORD FAILURE *Type of Failure*  
TEST RESPONSE = 053412 ( 6.7999 VOLTS) .7001 VOLT ERROR *Value Received & Magnitude of Error*  
TEST COMMAND = 060000 ( 7.5000 VOLTS) .0049 VOLT TOLERANCE *Value Sent & Analog Tolerance*  
TEST RESPONSE SHOULD BE IN THE RANGE 7.4951 TO 7.5049 VOLTS

ERROR NO. 2 SYSTEM CARD ADDRESS = 169 WORD ADDRESS = 2  
DISCRETE BIT WORD FAILURE  
RESPONSE VALUE = 001231 SHOULD BE TEST VALUE = 000377  
RESPONSE VALUE = 101010 SHOULD BE TEST VALUE = 177777

ERROR NO. 3 SYSTEM CARD ADDRESS = 171 WORD ADDRESS = 0  
TEST A/D OR D/A FAILURE  
TEST RESPONSE = 125252 ( 6.6669 VOLTS) 6.8228 VOLT ERROR  
TEST COMMAND = 000777 ( .1559 VOLTS) .0049 VOLT TOLERANCE  
TEST RESPONSE SHOULD BE IN THE RANGE .1510 TO .1609 VOLTS

ERROR DIAGNOSTICS COMPLETED

CW 7621.100037.2000  
CW 7624.24040.52200.177504.53200  
DS 4000.7777

FIGURE 4 ERROR PRINTOUT

- o Advanced Packaging Concept - The packaging space required by the system is only 20% of that required by previous systems. Figure 5 shows an equipment comparison for a number of recent simulators. In effect, a full single-bay cabinet is reducible by AST design to a single card bin. Figure 6 shows the

<u>SIMULATOR</u>	<u>PRESENT SYSTEM CABINETS</u>	<u>AST SYSTEM CARD BINS</u>
P-3C	5	6
KC-130	5	5
F-5E	2	2
DC-9	4	5
727	4	5

AVERAGE SPACE REDUCTION: 80%

FIGURE 5 EQUIPMENT PACKAGING COMPARISON

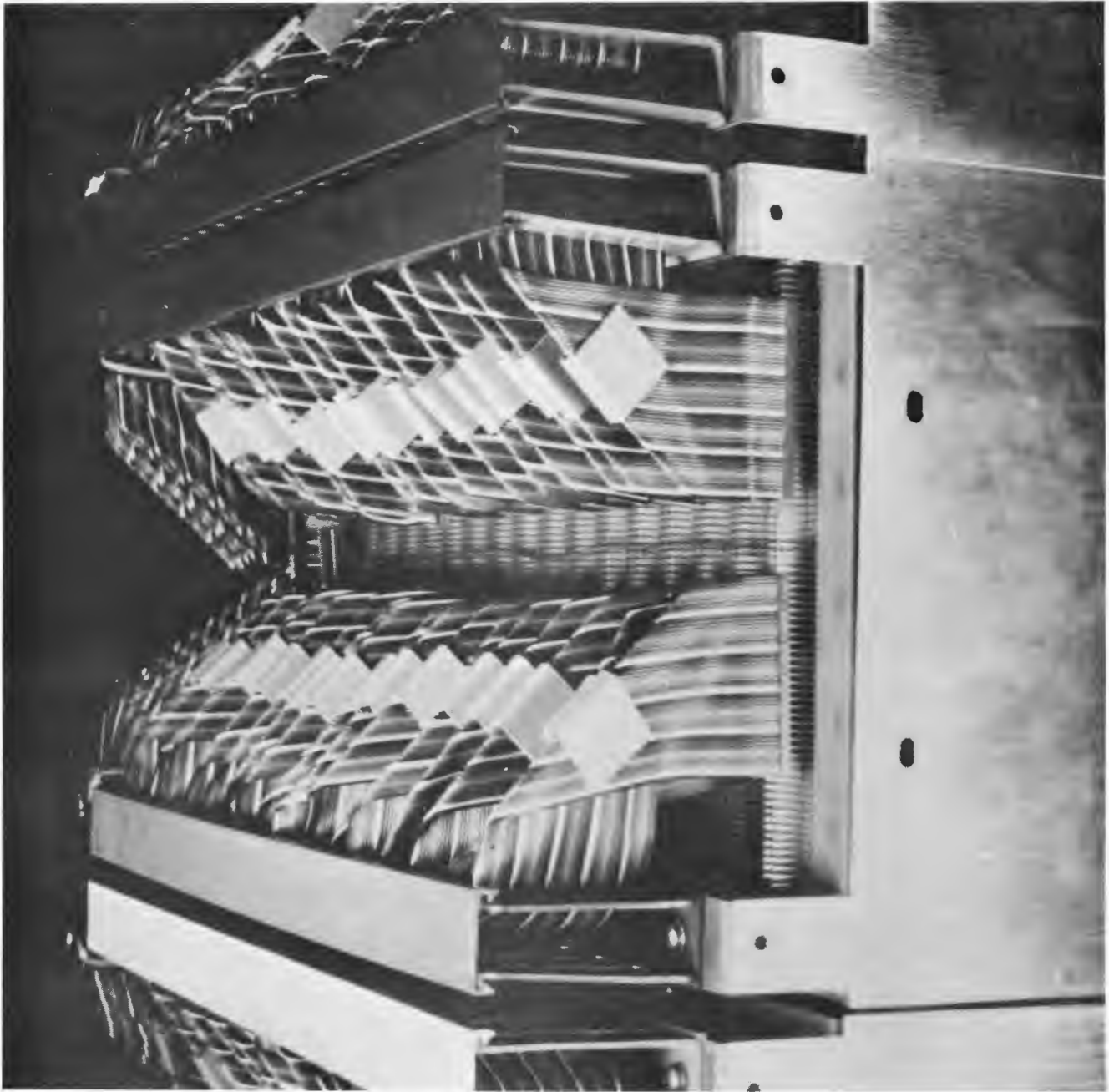


Figure 6 AST ELECTRONIC PACKAGING  
(showing ribbon cables connecting  
backplane of printed circuit file  
to flight compartment instrumentation)

impact of the bus concept in reducing interconnections and cable systems. These breakthroughs have permitted the development of an entirely new simulator packaging concept, which is explained in more detail following discussion of the other four phases of the AST program.

#### Power Distribution System

Present power distribution systems are based upon the ground "tree" concept to avoid circulating current and reduce noise. Unfortunately, total isolation of power and grounds internal to solid-state components, coupled with combining of power grounds within some aircraft parts, defeats the utility and performance of this approach.

The AST power distribution concept is based upon two main principles. First, power supplies are distributed and located near the electronics they drive. Second, a ground "plane" or bus concept is used to distribute DC power. The electronics cards, the system card files, and the power supplies to the files are all interconnected by bus, thus providing a very low-impedance plane which results in minimum noise on power and grounds.

The DC power systems include fault detection and monitoring. Should a supply fail, power is automatically removed from the local power supplies to prevent inadvertent damage to aircraft instruments, and the master controller of the AST interconnection system is alerted to the failure.

A single-bay AC power distribution cabinet controls and distributes all AC power received from the facility by the simulator. The principal features incorporated in this assembly are an automatic power sequence designed with high noise immunity logic, complete monitoring of AC power systems, and remote manual power control capability. The AC distribution within the unit includes circuit breaker protection of individual lines and utilities, and a copper bus structure design to simplify wiring and provide exceptional access for periodic maintenance.

## Aural Cue System

The AST aural cue system takes advantage of the system card structure of the AST interconnection system. As depicted in Figure 7, all electronics cards interface directly with the interconnection bus. The aural cue system cards thus contain all electronics, including I/O conversion and test hardware, associated with sound simulation. Figure 8 provides a direct comparison of conventional versus AST aural cue design.

The AST aural cue system provides quadraphonic outputs, so that sound directionality is included in the simulation. Typical sounds provided by the system are:

Hydraulic Pumps  
Ground Power Start  
Taxi Rumble  
Wheel Screech  
Strut Compression  
Landing Gear/Door  
Flap Extension

Turbine Whine  
Compressor Fan  
Exhaust Noise  
Aerodynamics  
Cabin Ventilation  
Inverter

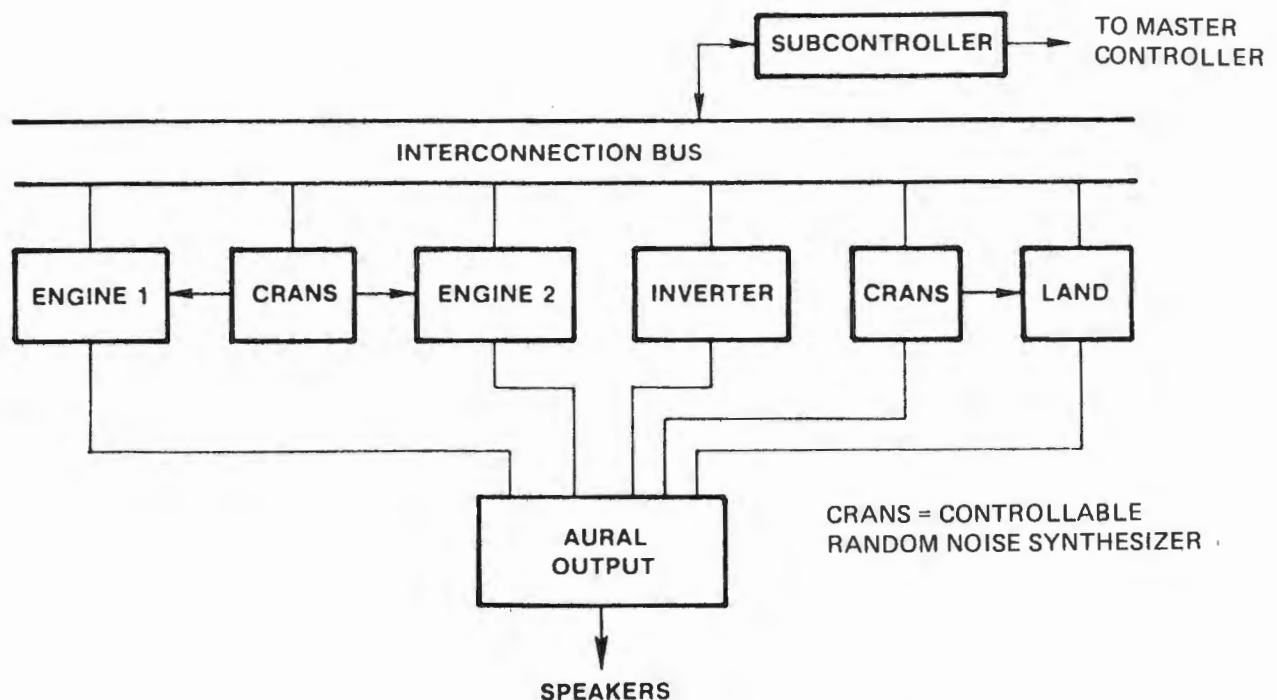


FIGURE 7 TYPICAL AST AURAL CUE SYSTEM

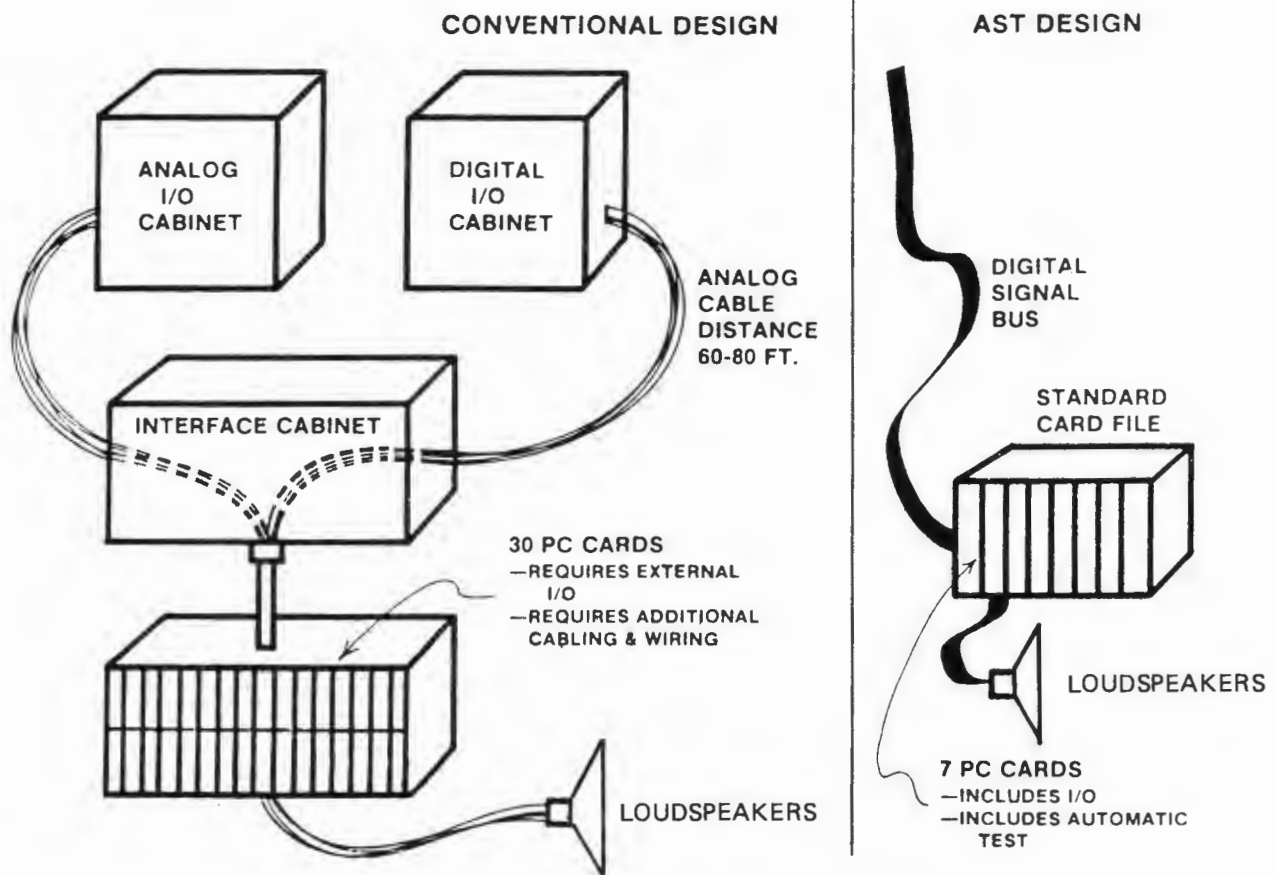


FIGURE 8 AURAL CUE SYSTEM COMPARISON

### Control Loading System

The AST control loading system, designed to improve system response and force characteristics, employs a hybrid (digital/analog) electronics concept which, while insuring accuracy, resolution, and smoothness of integration, allows certain control loading characteristics to be programmed digitally.

The control loading unit is an integral assembly designed to minimize mechanical play by providing direct shaft linear coupling of the actuator to its force input and to the transducers. A low-friction actuator is utilized to ensure high system performance and overall system response. The assembly includes electromechanical bypassing and sensing circuitry to limit stick forces outside the simulated regime as a safety feature, in the event of equipment failures.

The electronics for each primary flight control are located on a printed circuit card which also includes the required I/O conversion and test hardware. The dedicated D/A converters used on the PC cards result in short analog signal runs, thus improving signal/noise ratios and consequently servo loop response. Control loading PC cards interface directly with the AST interconnection bus.

Figure 9 provides a direct comparison of the AST control loading electronics design versus the conventional design approach.

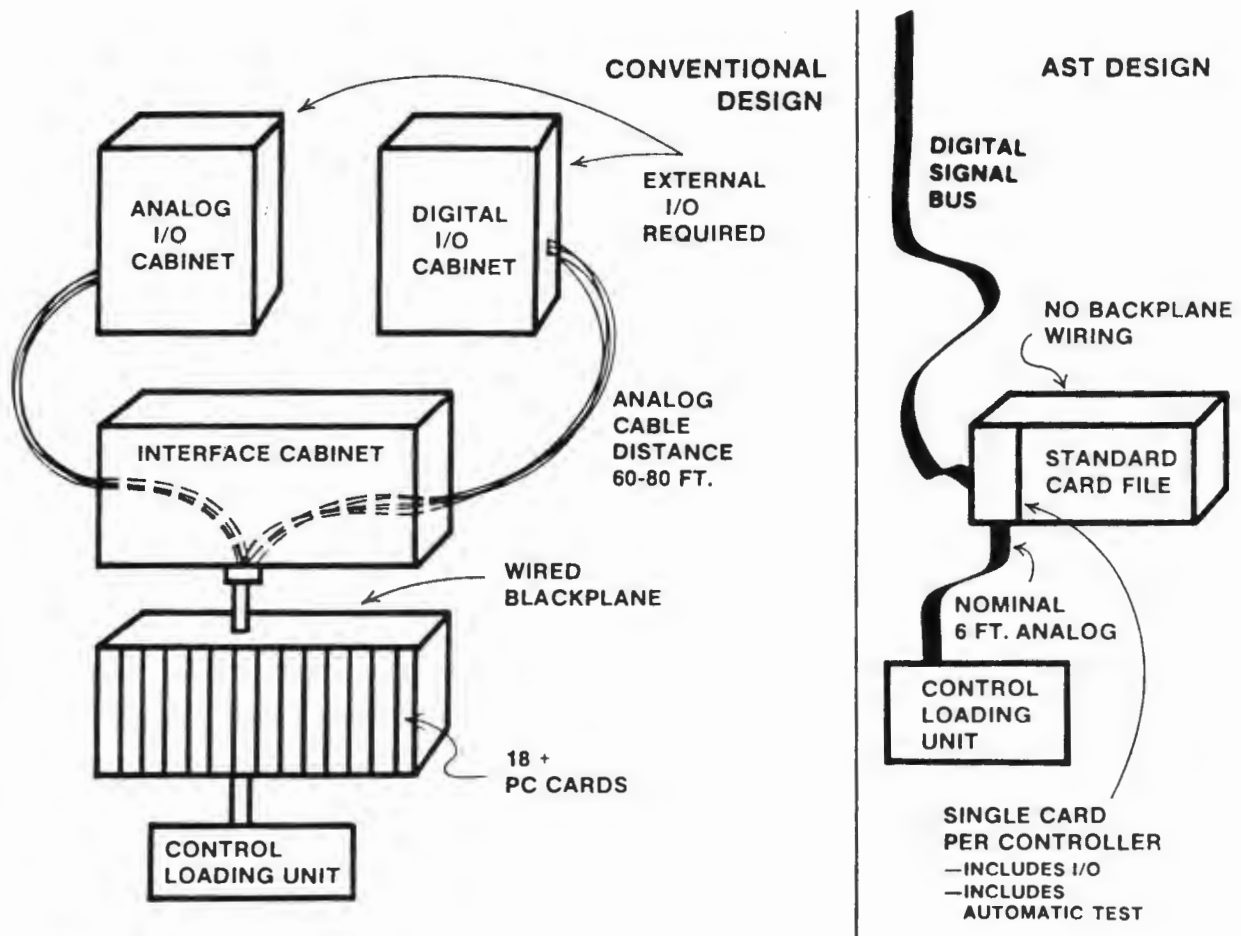


FIGURE 9 CONTROL LOADING ELECTRONICS COMPARISON

## Motion System

The AST motion system is a six-degree-of-freedom synergistic system of an entirely new design employing advanced development concepts to provide significant improvements in motion performance. Simplified platform, joint, plumbing, and electronic assemblies are designed to facilitate maintenance, reduce the chance of oil leaks, and improve equipment accessibility.

The most significant technical breakthrough was the successful development of the high-performance actuator assembly. A unique hydrostatic bearing design has successfully solved the actuator "friction" problem, which produces an undesirable "bump" in the motion cues of conventional 6-DOF systems. The substantial reduction in friction levels allows smoothness of responses in the  $\pm 0.02g$  regime, a figure that cannot be approached by conventional actuator design.

An ultrasonic linear displacement transducer eliminates all mechanical coupling between the actuator and the sensor, resulting in an extremely clean (noise-free) position feedback signal which can be differentiated electronically to obtain a velocity compensation term for the actuator servo control loop. The use of velocity and pressure feedback compensation in the servo design gives the AST motion system superior frequency response and damping characteristics.

Also unique to the actuator assembly is an "in line" cushion design based upon piccolo orifices. This results in a smooth system erection and also (more importantly) provides an energy absorbing technique that is foolproof in nature and limits G forces imparted to the cockpit, under worst-case failure condition, to totally acceptable levels.

High-flow-capacity servo control valves virtually eliminate hydraulic fluid noise at the motion base, resulting in quiet system performance even when high acceleration and velocity rates are commanded.

The hydrostatic bearing causes a pressure differential across its surface such that pressure on the upper collector/actuator wiper is essentially zero, with bypassed

fluid being returned to the system via a drain line. In conjunction with a major reduction of pipe connections in the plumbing installation, and a reduction of system pressure over past systems, the possibility of oil leakage is minimized.

The AST motion system geometry is optimized to place the motion platform closer to the floor. The new geometry also reduces dynamic leg and floor loadings, and increases the amount of excursion available for motion cues. Figure 10 shows the AST motion system in its settled position.

Design of the motion system to operate at lower system pressure allowed the use of vane pumps in lieu of a variable-displacement piston-type pump, resulting in a significant reduction of noise levels in the pump room. This will simplify pump room design and result in lower facility costs to the user.

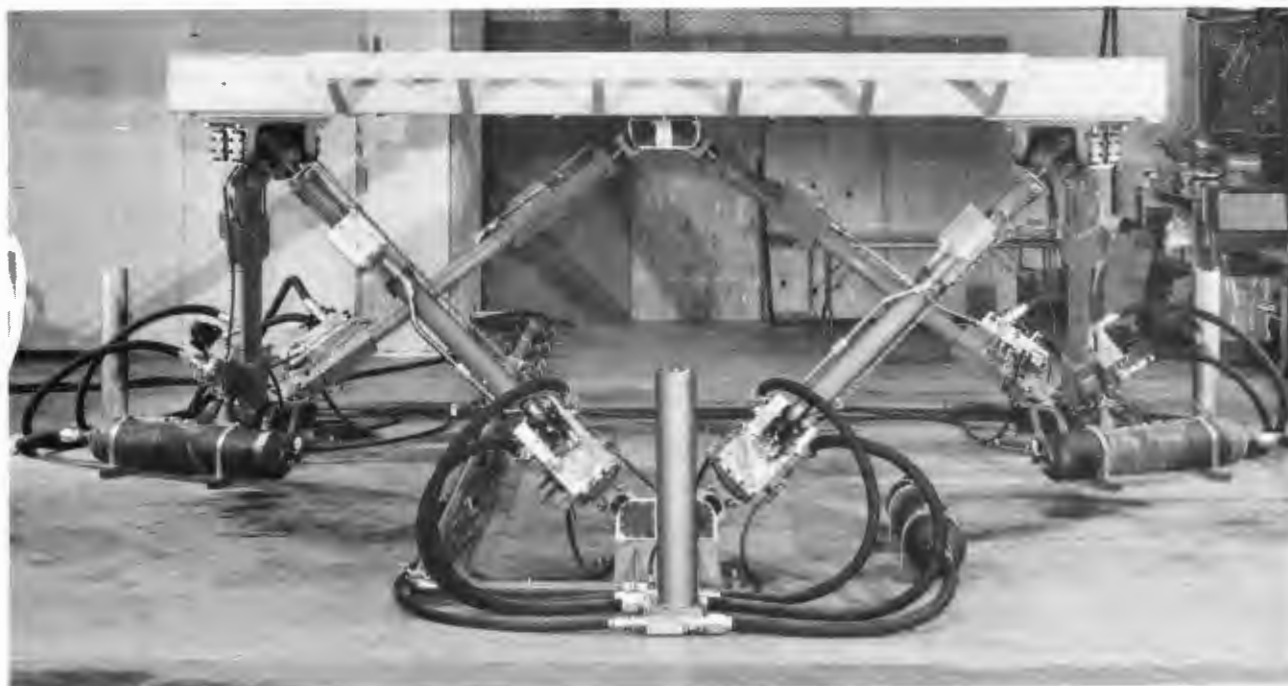


FIGURE 10 AST MOTION SYSTEM IN SETTLED POSITION

The hydraulic power supply is a completely self-contained unit which has a large reservoir capacity and a separate pump which operates with a parallel heat exchanger, thus allowing the system to operate at lower oil temperatures than past designs. A separate control loading pump is also part of the unit.

The AST motion electronics is packaged in a low-profile single-bay cabinet. Primary assemblies of the unit are a self-contained power supply system, an AST interconnection system, card file with motion PC cards, and the maintenance control panel.

The motion electronics communicates directly with the AST interconnection bus and requires only four different PC board types. A comparison of AST versus conventional motion electronics is shown in Figure 11, to illustrate the difference between these systems.

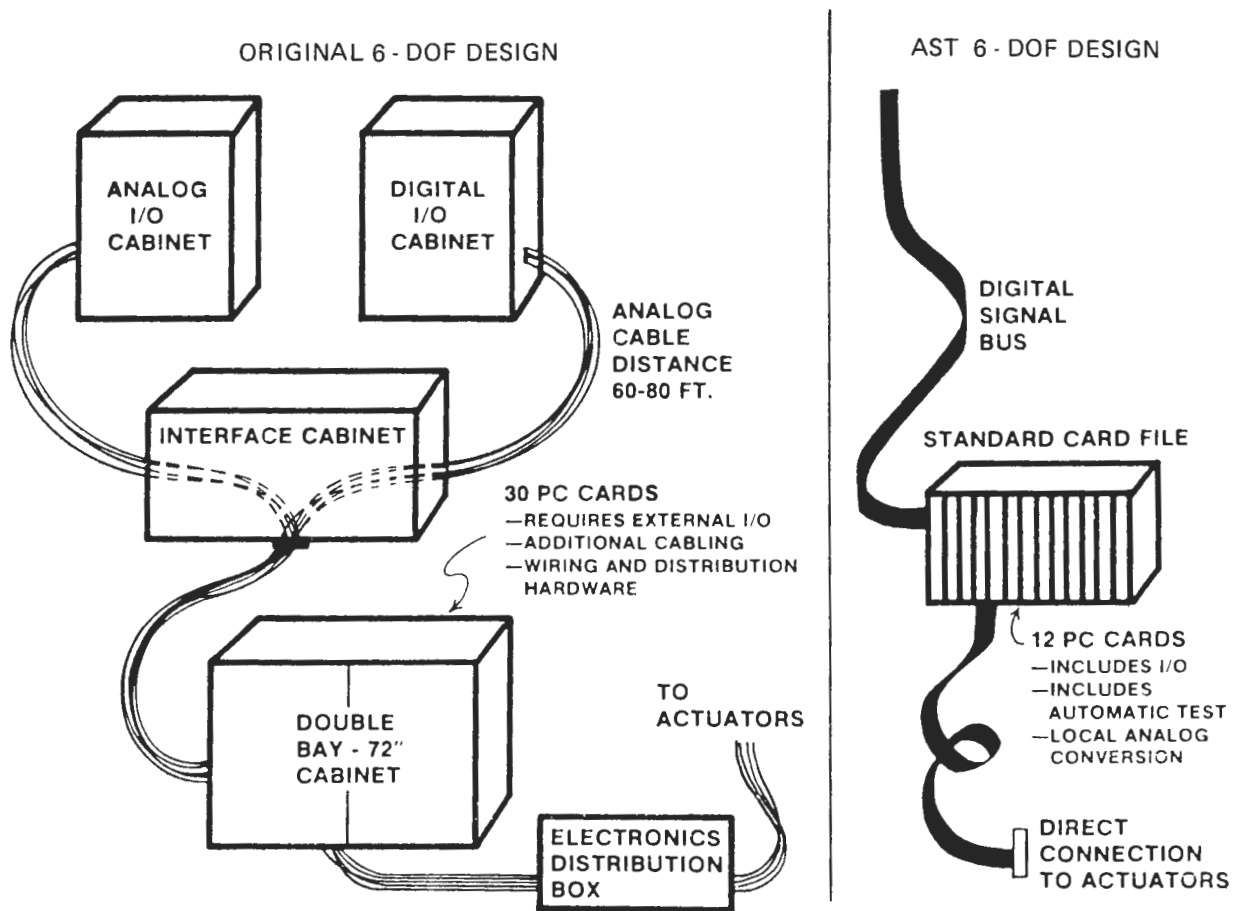


FIGURE 11 MOTION ELECTRONICS COMPARISON

### Advanced Simulator Packaging Concept

As mentioned earlier, the AST concepts of digital bus interconnection and distributed interface electronics have made possible an entirely new approach to flight simulator packaging, one that abandons the traditional esthetic preference for aircraft-like flight compartment exterior design in favor of an all-encompassing electronic equipment and visual display system enclosure design that offers significant operating and maintenance advantages to the user while preserving, and even improving, the integrity of the flight crew compartment interior design.

To arrive at the equipment packaging approach, Link analyzed a number of transport aircraft flight compartments, including the 707, 737, 727, 747, DC-10, and L-1011, in terms of the physical location of all aircraft equipment. The result was the composite layout shown in Figure 12. A concept was then advanced to place the electronics in the optimum location, keeping in mind that maximum benefit accrues when electronic equipment is located as close as possible to the aircraft hardware it services. Once the equipment was placed, access for maintenance was considered. The resulting enclosure design is shown in Figure 13.

The modularization achieved by the new packaging approach results in maximum benefits for maintenance personnel. An instrument panel module, for example, is driven from card files that are dedicated entirely to that module. This results in short and straightforward cable runs to the assembly. It also means that all electronics for the module are placed in a single location, which greatly simplifies troubleshooting.

By locating the equipment as shown in Figure 13, a balanced load with respect to the CG point of the motion system is achieved, and since the equipment is close to the motion centroid, reduced moments of inertia are obtained.

The advantages of this advanced simulator packaging concept are numerous:

- 1) Controlled Environmental System. The enclosure allows the creation of a closed environment system which greatly facilitates personnel air conditioning and equipment cooling and results in a clean equipment environment.

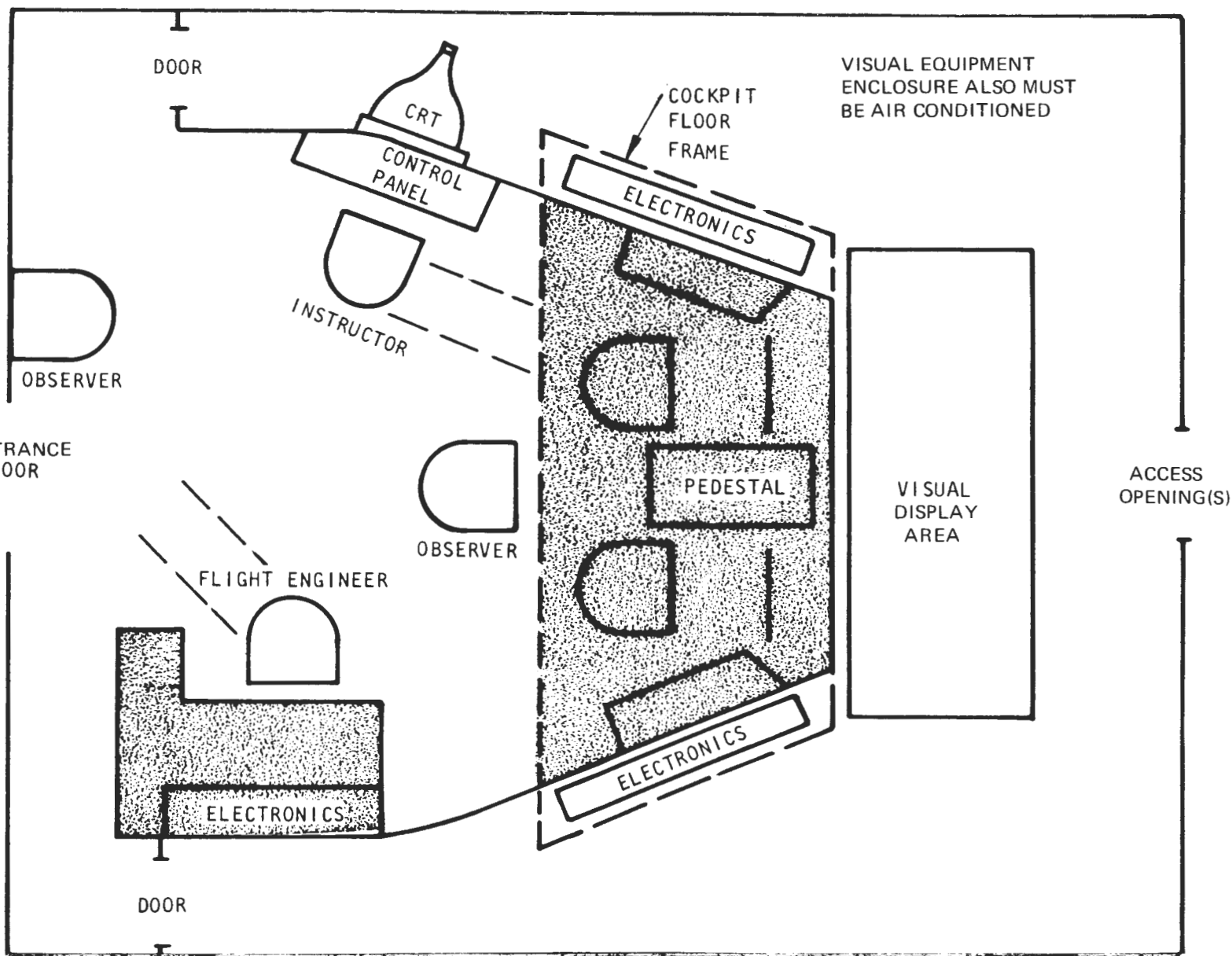


FIGURE 12 COMPOSITE FLIGHT COMPARTMENT LAYOUT

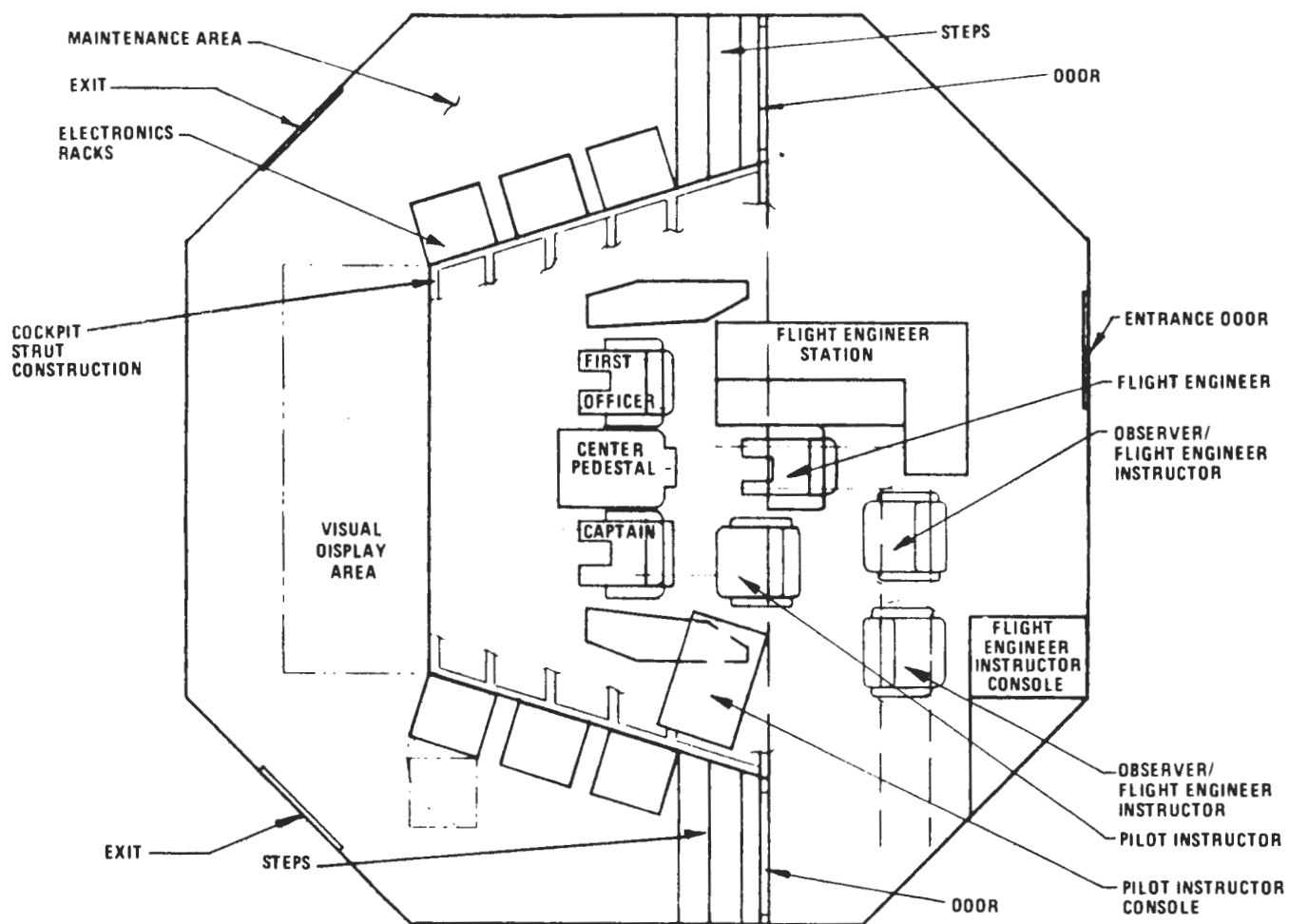


FIGURE 13 TYPICAL SIMULATOR ENCLOSURE ARRANGEMENT

The location of the air conditioners eliminates most of the ductwork found in present-day simulators.

- 2) Visual Enclosure. The enclosure is light-tight, thus eliminating the need for an external visual enclosure.
- 3) Open-Rack Construction. The open-rack construction, in conjunction with electronics being mounted in hinged gate assemblies, maximizes equipment serviceability.
- 4) Cockpit Strut Construction. With this type of construction, maintenance can be accomplished from the outside as well as inside.
- 5) Improved Cockpit Interior. There is no need to package simulation electronics in the cockpit interior. Therefore, the area is left uncluttered and looks more like the aircraft in appearance.
- 6) Reduced Facility Floor Space. With all equipment (except the AC power, motion, and computer cabinets) being packaged in the simulator enclosure, a reduction in facility floor space results.
- 7) Fire Extinguishing System. The enclosure provides a means by which an efficient and economical fire detection and extinguishing system can be provided.
- 8) Optimized Locations for Instructor Stations. The physical configuration and additional room in the cockpit area allow optimization of the instructor's location, so that the instructor can look over the trainees' shoulders and simultaneously operate the instructor controls without physically shifting his position.
- 9) Improved Ancillary Systems. A number of simulator ancillary systems, including normal and emergency lighting, ingress/egress staircase, and instructor chairs have been redesigned and improved.

## SUMMARY

Link's Advanced Simulation Technology program represents a major departure from the design of past simulators. The scope of technological change, as evident herein, covers virtually all systems that comprise a flight simulator. The resulting AST simulator, especially if fitted with the recently developed LINK\* Night Visual System, is a truly unique and greatly improved product, designed to meet future training demands without a corresponding increase in simulator life cycle costs.

Link is pleased to be able to offer its customers this new product line, and to be able to contribute in its own way to the cost-effectiveness of airline industry operations in this era of rising operational costs and limited energy resources.

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